HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the joint supervision of the
UNIVERSITY OF HAWAII
and the
UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN NO. 70

THE MANUFACTURE OF POI FROM TARO IN HAWAII: WITH SPECIAL EMPHASIS UPON ITS FERMENTATION

By

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and
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Issued November, 1933.

UNIVERSITY OF HAWAII
Honolulu, T. H.

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(Under the joint supervision of the University of Hawaii, and the Office of Experiment Stations, United States Department of Agriculture.)

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ERRATA

p. 18, line 1 in 3rd ¶—"righ" should be "high."

p. 23, line 16 from top—"increasingly" should be "increasing."

p. 26, line 6 from bottom—"success values" should be "sucrose values."

p. 26, line 4 from bottom—"to 0.159 percent" should be "to 0.0159 percent."

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INTRODUCTION

Taro (*Colocasia esculenta* (L). Schott var. *antiquorum* (Schott) Hubbard and Rehder (*22*)[3], one of the most important food crops of many tropical countries, is well known throughout the Hawaiian Islands as the principal source of a fermented food called *poi*, which has been commonly referred to as "the staff of life" of the native Hawaiians. This fermented product is considered an important food at the present time.

The purpose of this bulletin is to review the history and present conditions of taro culture and poi making in Hawaii, and especially to discuss the preparation of poi from the bacteriological standpoint. The subject is especially timely because of increasing interest in the use of poi as a hospital and infant food.

[1] The authors wish to express their thanks to F. G. Krauss, Director of Cooperative Agricultural Extension Service, University of Hawaii, and to T. G. Yunker, Professor of Botany, De Pauw University, Greencastle, Indiana, for their helpful criticisms and timely suggestions in the preparation of this bulletin.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 30ff.

TARO

Distribution

The *colocasias* or taros are generally considered to be the most important group of the edible *aroids*. The plant is common in various tropical regions, approximately 300 distinct varieties being known according to Barrett (*6*). A botanical description of the plant and a summary of the conditions under which it thrives best will not be considered here. The interested reader is referred to the works of Higgins (*21*) and Sedgwick (*37*) on these subjects. When or how the taro came to Hawaii is not known. In view of its distinct place in the lives of the Polynesian races there is reason to believe that taro was carried by them to various South Sea Islands, whence it rapidly spread to other tropical islands, including Hawaii. Brown (*12*) states that the taro was introduced into the Marquesas Islands from Hawaii by "Tueni, a Hawaiian who came ashore in the valley of Hakaui (Marquesas) from a burning ship bringing the Hawaiian taro with him."

The dasheen is probably the best known of the taros in temperate regions. It has recently attracted attention in the southeastern United States as a possible substitute for the common potato. The term "dasheen" is thought by Young (*47*) to have been derived from the expression *de Chine*, thus signifying that this particular variety came from China. Barrett (*5*) recognizes as the only difference between taro and dasheen the presence of small tuberous outgrowths on the corms of the latter. Apparently there is little difference between the true taro and the dasheen, and in this bulletin the terms "dasheen" and "taro" are used synonomously.

Composition

The taro and the dasheen have been analyzed by various investigators (*32*) (*34*) (*47*). Results of taro analyses, as well as of comparable food plants, compiled by Chatfield and Adams (*13*) are given in table 1.

TABLE 1.—COMPOSITION OF TARO, DASHEEN, POTATO, AND SWEET POTATO

Crop	PERCENTAGE									CALORIES	
										Fuel Value	
	Refuse	Water	Protein (N x 6.25)	Fat	Ash	Carbohydrates (total difference including fiber)	Fiber	Sugar	Starch	Per 100 grams	Per 1 Pound
Taro (corms and tubers)	18.0	75.1	2.0	0.2	1.17	21.5	0.8	1.42	18.2	95.8	435
Dasheen (corms and tubers)	16.0	66.6	2.9	0.2	1.42	28.9	0.7	1.71	21.8	129.0	585
Potato	16.0	77.8	2.0	0.1	.99	19.1	0.4	0.87	14.7	85.3	385
Sweet potato	14.0	68.5	1.8	0.7	1.07	27.9	1.0	5.35	20.2	125.1	565

Uses

The entire taro plant serves as a source of food in many of its habitats. The natives of Guam have been known to cook the large taro leaves and use them as spinach or asparagus is used (*36*). Ochse (*35*) states that the people of Java eat the small rhizomes steamed or boiled and sprinkled with coconut and that the cooked corms mixed with rice is a common dish among the Javanese, who also prepare jelly from the old leaves by pounding and steaming them. He also reports that taro leaves, probably because of their slimy latex, are sometimes used as a substitute for soap. The roots, stems, and leaves cannot be eaten raw because of their irritating effect upon the mucous membrane of the mouth. This irritation has been commonly attributed to the presence of calcium oxalate crystals in the plant cells. Pedler and Warden according to MacCaughey and Emerson (*30b*) were the first to demonstrate the presence and action of calcium oxalate crystals in species of the family *Araceae*. The former investigators offered a mechanical explanation for the irritating effects caused by contact with the needle-like crystals. Later Safford (*36*) described the ejection of the crystals from their capsules in the presence of water. Safford was successful in demonstrating that the irritation was chiefly due to the force exerted when the crystals were ejected from the capsule. In 1918 Black (*9*) confirmed this fact and in addition showed that the capsules lost their ability to expel crystals after the plant had been cooked or dried.

In Hawaii taro is used chiefly for poi manufacture. Poi was prepared by the early Hawaiians by hand crushing cooked taro in poi bowls or trays, mixing the mashed corms with water, and subsequently incubating the paste in the warm ground, or in covered gourds exposed to direct sunlight. Ochse (*35*), Cook and Collins (*17*), Borg (*10*), and Safford (*36*), who have reviewed the botanical characteristics of the taro plant and its uses in Java, Puerto Rico, Malta, and Guam make no mention of the fermentation of the corms to prepare a food resembling Hawaiian poi.

Status of Culture in Hawaii

Several articles dealing with the economic importance of taro culture in Hawaii have been published in the last decade. Describing the general situation Crawford (*18*) says:

> Taro and poi have a unique place in the diet of certain groups of our people, but it appears that the demand is decreasing as the price is increasing. Other foods are taking the place of this ancient standby, for already it has become a relatively expensive food. Efforts should be made to decrease the cost of production by increasing the yields. If this is not practiced the taro crop may follow rice into the discard, unless the present effort of one local company should be successful in making a high priced export specialty in the form of taro flour.

Freeman (*20*), in 1927, listed, for the year 1899, 441 farms on which taro was cultivated and estimated the value of the crop at $187,310. Sedgwick (*37*), in 1902, ranked taro in fourth place

in terms of area in cultivation and from a standpoint of total value of the crop. For the same year Sedgwick (*37*) estimated the investment in taro to be between $450,000 and $500,000. Bailey (*3*) also ranked taro as the fourth crop of importance in Hawaii for 1913. Crawford (*18*) estimated the total yield and consumption of taro to be 10,000,000 pounds in 1929 with a market value of about $200,000. MacCaughey and Emerson (*30*) (*31*) and MacCaughey (*32*) give the status of taro and poi in Hawaii for the years 1913 to 1917. Data regarding area and yields from 1928 to 1932, furnished by Lund and Krauss (*29*) of the University of Hawaii, are given in table 2.

TABLE 2.—APPROXIMATE AREA AND YIELDS OF HAWAIIAN TARO ON THE ISLAND OF OAHU FOR THE PERIOD 1928-32.

Year	Area in cultivation	Total yields of taro corms	Average acre yields of taro corms
	Acres	*Pounds*	*Pounds*
1928	380	11,250,000	29,605
1929	387	14,126,100	36,500
1930	375	11,250,000	30,000
1931	370	10,377,003	28,045
1932	360	10,809,300	30,026

Two generally recognized types of taro for poi making are in cultivation—Japanese or dry-land taro which has a growing season of from 7 to 8 months and yields about 6 tons of corms to the acre, and Hawaiian or wet-land taro which has a growing season of from 7 to 14 months and yields from 4 to 18 tons to the acre.

Lund and Krauss (*29*) state that at the present time there are approximately 25 acres in Japanese taro and approximately 360 acres in Hawaiian taro on the island of Oahu. The latter figure agrees very closely with the estimate given in the semi-annual report of the Territorial Board of Health poi inspector for June, 1932. The yield, of course, varies greatly in different localities and under different methods of planting.

MacCaughey and Emerson (*30 c, d, e*), in 1913 tabulated 266 names and synonyms of distinctly different varieties of taro that have been in cultivation in the Hawaiian Islands at some time. About 15 varieties of Japanese taro and 32 varieties of Hawaiian taro are thought to be in cultivation at present (*44*). These are best known under their Hawaiian names. Among those being used by factories are *piialii, pikokea, piko, hapuupuu, makapio, ipuolono, kaolea, kaieleele, laulea, haakea, apuwai, palai'e,* and *lehua*. The common red poi, made from the *piialii* variety instead of from the *lehua* variety as is generally thought, is the most popular product in the factories.

POI

Historical Significance in Hawaii

The importance of poi as a food of the native Hawaiians is well established in the early historical accounts of the islands. Captain Cook (*16*), in the following quotation, gives the earliest reference to taro and poi in Hawaii:

> Judging from what we saw growing and what was brought to market there can be no doubt that the greatest part of their vegetable diet consists of sweet potatoes, taro, and plantains.... The only artificial dish we met with was a taro pudding; which, though a disagreeable mess from its sourness, was greedily devoured by the natives.

Stewart (*39*), in 1828, stated that

> taro....is the principal food of the Sandwich Islanders, and to the whole nation answers the double purpose of vegetables and bread....
>
> The natives prepare it for use, first, by baking it, in the only manner practiced by them. This is, by digging a hole in the ground a foot or two deep, and five or six feet in circumference, and placing a layer of stones on the bottom, upon which light wood is placed and fire kindled. Other stones are laid upon the fire, and by the burning of the wood the whole becomes ignited. Those on the top are drawn off and the taro, or the potatoes, or fish, pig, or dog, etc., closely wrapped in the leaves of the banana or of the ti, is laid on the hearth of stones still remaining at the bottom, and immediately covered with the rest. A little water is poured on the pile to create a steam, and the whole hastily buried with earth, by which the heat and steam are kept from escaping, and the article in the *umai* or oven becomes baked.
>
> The taro, after being thus cooked, is in the next place made into the favourite *poe*. The process in this is simple, though so laborious as to be performed only by the men. It is merely by beating the taro upon a short plank of hard wood, slightly hollowed in the middle like a tray, with a stone something in the shape of a thick and clumsy pestle, wetting it occasionally with water, and moulding it until it becomes an adhesive mass like dough. It is then put into a calabash, diluted with water till the consistency of paste and set aside for fermentation. This soon takes place and the *poe* is fit for use in a day or two, though preferred when four or five days old.
>
> Hard or dry *poe* is taro baked and beaten in the manner described, but not moistened with water. It is not much eaten in this state; but is packed in small bundles, and bound in leaves, to be diluted and formed into soft *poe* at pleasure. In this manner it will keep without injury for months; and it makes a principal article in the sea stores of the native vessels.
>
> We find taro a pleasant vegetable. It is most excellent when cut into slices and fried, after being baked or boiled, though less nutritive than in the form of *poe*.

Ellis (*19*), in 1832, placed the taro second only to the breadfruit in importance as a food in Hawaii, and stated that 33 different varieties of taro were then used by the Hawaiians in the making of poi. He also mentioned the making of flour from taro corms when food supplies were scarce. Jarves (*24*) and Cheever (*14*), in 1843 and in 1850, respectively, also indicated the important place occupied by poi in Hawaii. Thrum (*40*), in

1880, enumerated 28 varieties of taro for poi making. Poi from the *lehua* and *puau* varieties was especially esteemed by the native chiefs. These varieties are said to be still in cultivation.

Various attempts were made since 1879 to manufacture and establish a market for taro flour. *Taroena* and *Taro Mano* have been the best known brands introduced during this time but each failed to exist as a commercial product. A product called *Taro Maloo,* closely resembling macaroni, was introduced between 1900 and 1910. Unfortunately this product did not meet with favor from a commercial standpoint.

Present Methods of Manufacture

Most of the taro used in poi making in Honolulu and its vicinity is of the wet-land variety, but some poi is made from a mixture of both wet-land and dry-land varieties. Corms of wet-land taro are usually collected by hand. Dry-land taro is occasionally gathered with spades or with picks or is plowed out as in the harvesting of potatoes. Immediately after the taro is harvested the young shoots are carefully removed from the corms and reserved for future planting. Usually, the same field is replanted with these young shoots shortly following the removal of the previous crop.

In general, the actual manufacture of poi consists of two major processes: (1) The cooking, peeling, and grinding or pounding of the taro corms; and (2) the incubation and fermentation of the crushed product (fig. 1). The taro is loaded on large carts, covered with tarpaulins or sacks, and conveyed into a hooded inclosure into which steam can be injected. Steam is then passed through the cart of taro for from three to four hours, the temperature ranging from 70° to 100° C. In most factories the length and the temperature of the cooking period are not recorded, because the degree of cooking is indicated by a change in the color of the interior of the corms from white to dark purple. When the taro is considered cooked, the sacks or tarpaulins are removed and the cooked taro is rapidly cooled with a small stream of water from a hose. This is usually the first treatment with water, and it removes much of the adhering soil.

As soon as the taro is cool enough to be handled it is transferred to a trough where it is washed in running water, peeled, trimmed, and scraped. The corms are then carried in barrels to a grinding machine. The best poi usually is finely ground, but so-called "lumpy poi" is favored by some consumers. After it has passed through the grinding machine the taro is mixed with water. The resultant product is known as fresh poi.

Three kinds of poi may result, depending upon the amount of water added to the *paiai;* [4] *one finger poi,* signifying a con-

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[4] The term *paiai* has generally been applied to cooked taro corms pressed together in ti (*Cordyline terminalis* Kunth) leaves. *Paiai* undergoes little, if any, fermentation in this state, but, following the addition of water and a period of incubation, subsequently ferments into poi.

A *Photo Courtesy of Honolulu Star-Bulletin.*

B *Photo Courtesy of Honolulu Star-Bulletin.*

FIGURE 1.—A poi factory. A, Background, taro heating bin; foreground, troughs for washing the steamed taro and barrels in which to incubate the poi. B, Grinding the taro and mixing the poi with water prior to incubation.

sistency thick enough to be satisfactorily eaten with ease by using one finger; *two finger poi,* being more watery and thus requiring the cup of two fingers for a satisfactory helping; and *three finger poi,* which is so thin that a cup formed by three fingers is necessary for a helping. One and two finger poi seem to be the most desired consistencies at the present time. Stewart (*39*) in 1828 remarked:

> It (poi) is eaten by thrusting the forefinger of the right hand into the mass and securing as much as will adhere to it and passing it to the mouth, with a hasty revolving motion of the hand and finger. The only name of the forefinger is derived from this use of it *Ka rima poe,* "the finger poe" or poe finger. The second finger is often used; and not infrequently the thumb at the same time. This is the usual mode of eating it .... a dozen or more from one calabash; but I have seen the calabash taken up with both hands and applied to the mouth as in drinking; and thus passed from one to another, around the group.

Poi should contain 30 percent by weight of solid matter (See Regulation of Manufacture below). For sour poi the barrels are incubated at room temperature for a day or longer. As fermentation progresses the poi begins to puff or swell slightly. In poi made from the *piialii* variety of taro the puffing is usually accompanied by a change in color from purple to pink, whereas in the other common varieties bleaching generally results. Many native Hawaiians are able to judge the age of poi fairly accurately by the degree of change in its color. The progress of fermentation is also indicated by a change in texture from a very sticky mass to one having a more watery and fluffy consistency, by development of acetic esters, and increasing acidity.

The nature of the fermentation of poi as indicated by the gross changes in texture, color, and consistency suggests the presence of microorganisms as the causal agents. So far as could be ascertained no inoculum or starter is introduced during any stage of the manufacture. As a rule, the daily production of poi equals the daily consumption of the product. When this is not the case the old poi is commonly discarded.

Conditions in the factory during the preparation of poi are as clean and sanitary as could be expected, and there is reason to believe that they do not affect fermentation. The refuse resulting from peeling and cleaning of the cooked taros is constantly carted away. Running tap water is used in rinsing the peeled corms. The floor of the factory is usually covered with running water and there is practically no dust. At the close of each working day the crushing machine is dismantled, and the exterior and the interior parts, including knives and grinding cylinders, are carefully washed. In like manner, all the barrels, utensils, and troughs used are thoroughly washed and dried. These utensils are generally steamed two or three times each week.

Regulation of Manufacture

The making of poi is regulated by law, and general sanitary measures are enforced by poi inspectors who regularly visit the

factories. The original law providing for such regulation was passed in 1911 as Act 77 in Section 3 of the Session Laws and revised in 1925. The essential provisions of the revised law are as follows:

Adulterated Food and Drugs: chap. 76, pages 455-457. Sec. 995. *Adulteration defined.* An article shall be deemed to be adulterated within the meaning of this chapter: (B) in the case of food: (9) in the case of poi, if it contains less than thirty per centum of total solids.

Manufacture of Poi: chap. 78, pages 461-462. Sec. 1011. *Only in buildings authorized.* No shop or building for the manufacture or sale of poi or *paiai* shall be erected, maintained, used or operated except as hereinafter provided.

Sec. 1012. *Erection and location of buildings, conditions.*—Every such shop or building shall be laid with cement floors, with cement walls to a height of at least two feet and draining to a trap connected with a cesspool, sewer, or such other means for the proper disposal of drainage, as may be approved by the board of health. No such shop or building shall be maintained, used or operated in any place where there is not available an adequate supply of pure water, or which is incapable of proper drainage, or which is so situated that the poi or *paiai* manufactured thereat might, in the opinion of said board, be contaminated or infected by reason of proximity to any stable, laundry, abattoir or other place at which any business or process is carried on or condition maintained which, in such opinion, might be a source of such contamination or infection; nor, while any such shop or building is being so used, shall any such stable, laundry, abattoir or other place be permitted to be established in such proximity thereto as to be, in the opinion of the board, a source of contamination or infection to the poi or *paiai* manufactured thereat. No such shop or building shall be maintained, used or operated for any other purpose than the manufacture of poi or *paiai;* nor unless only pure water shall be used thereat and proper drainage maintained thereof; nor unless it shall be kept so screened as to prevent flies and insects from entering therein; nor unless all implements, tools, machinery, containers, and all other utensils used for or in connection with the manufacture, distribution or storage of poi or *paiai* shall be sterilized each time before being so used; nor if any person or individual is employed or engaged in or about such shop or building who is afflicted with any contagious or infectious disease or any disease which, in the opinion of the board of health, may contaminate or infect the poi or *paiai.*

Factories in Operation

Thirteen factories are in operation on the island of Oahu, nine of which are in Honolulu. The ownership and management of the industry are largely in the hands of Chinese, although the employees represent various races of the island. The Kalihi Poi Factory, erected between 1890 and 1898, was the first factory to install a machine for the grinding of taro. Practically all the factories operating at the present time use machines for grinding the taro.

The average monthly production of poi by the 13 factories on Oahu in 1932 varied between 2,500 pounds by the smallest factory and 162,710 pounds by the largest one. Data

furnished by M. B. Bairos (*4*), Food Commissioner of the City of Honolulu concerning the yields of poi makes possible an estimation of 517,540 pounds as an average production per month by all factories for the year 1932 or an average production of 20,700 pounds per working day. A report by a former poi inspector for the period from January to July, 1932, showed the rural district factories manufacturing 92,175 pounds and the city factories a total of 3,017,283 pounds, compared to 3,113,109 pounds manufactured in the city during the same months of 1931. During the month of August, 1931, the largest factory on Oahu produced approximately 231,000 pounds or nearly 9,000 pounds of poi per working day (*27*).

Consumption and Nutritive Value

The average daily per capita consumption of poi can only be generally estimated. Information concerning native Hawaiian agriculture, as recorded by the missionaries, fails to show even an approximation of the acre yield of taro under the early mode of cultivation. Bates (*7*), in 1854, estimated that "forty square feet of land planted with *kalo* will afford subsistence for one person during a whole year. A square mile of land planted with the same vegetable will feed 15,151 persons for the same length of time."[5]

Thrum (*41*), in 1886, estimated that, allowing 28,000 pounds of *paiai* to the acre of taro and 4 pounds daily per capita, a square mile or 640 acres would provide subsistence for 12,274 men for one year. In this estimate the yields were expressed in terms of pounds of *paiai* (see footnote p. 6) rather than in pounds of taro to the acre. Since poi is approximately from 30 to 40 percent solids, 4 pounds of *paiai* a day would correspond to about 12 to 16 pounds of *poi*.

A former poi inspector of Honolulu is of the opinion that 5 pounds of commercial poi (30 percent solids) represents the average daily consumption of the adult who makes poi his principal food. However, the early Hawaiians are thought to have daily eaten from 10 to 20 pounds of poi, depending on the kind of work they did and the abundance of the supply of the product.

General information obtained at the present time from the local factories indicates that less poi is being consumed in the last few years. The lower prices of rice and flour and the Americanization of the younger generation of Hawaiians have been accepted as possible causes for such a decline. The following estimates expressed by Mr. Lum (*28*), manager of the See Wo Poi Factory, represent the amounts consumed on the Island of Oahu during the last six years:

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[5] This estimate is obviously incorrect as Bates evidently intended the use of the phrase 43 feet square, instead of 40 square feet.

TABLE 3.—POI CONSUMPTION ON OAHU FROM 1927-1932

Year	*Amounts of poi in pounds*
1927	5,880,000
1928	5 886.000
1929	6,782,000
1930	6,948,000
1931	6,361,200
1932	6,247,800

The value of poi as the staple food of the native Hawaiians can hardly be over-emphasized. Thrum (*40*), in 1879, was among the first to attribute the marvelous physical development of the Hawaiian to this food. MacCaughey and Emerson (*30*(*a*)), in 1913, said:

> If there is any relationship between food and physique, *kalo* is to be highly recommended, for the ancient Hawaiian, according to unanimous report, has a superb physical development. This statement must, however, be somewhat qualified. Among the Hawaiian women (and to a lesser degree among the men), especially after middle age, the poi diet has frequently a very marked fattening effect.... Not only has *kalo* gained wide repute because of the healthful and easily-digested food derived from it, but attention has also been attracted to its heavy yields per acre.

Barrett (*6*) observes that in the Kanaka language, which is the language of the poi-eating natives of Polynesia, "there is no word for indigestion."

Probably the earliest explanation for the easy digestibility of the taro was that of MacCaughey (*32*), who in 1917 based the characteristic upon the small size of the starch granule. His results showed the taro starch granule to range from 1 to 3 micra. Later Langworthy and Deuel (*25*) estimated the size of the granule to range between 1 and 7 micra. These authors also confirmed the results of Langworthy and Holmes (*26*) on the ready digestibility of the taro starch granule and showed that 98.88 percent of the starch was digested when humans were employed in the experimental tests. Further tests also showed that no undigested starch appeared in the feces even when 250 grams of starch were eaten in one day.

Scientific investigation of the nutritive value of taro and of poi has been comparatively recent. Practically no work of this kind on the taro or the dasheen had been done prior to that of Steenbock and Gross (*38*), who reported the dasheen to be a fair source of vitamin B, but devoid of vitamin A. Their results were obtained in feeding dried powdered dasheen in the basal diet of laboratory rats. Recently Miller (*34*) has shown that both taro and poi contain vitamin A—a lesser amount in poi than in taro due not to the heating in the process of making the poi but to the addition of water. Miller noted that taro and poi supply about half as much vitamin B as do the whole grains, including the embryo, and about twice as much as does milk. Vitamins C and D were not found in any appreciable amounts. Miller's results also seem to warrant the conclusion that persons subsisting principally on poi, supplemented with raw fish, *limu* (sea-

weed), and other foods, as is common in the Hawaiian diet, are able to supply their needs for calcium and phosphorus satisfactorily.

Experimental Methods

Samples of taro and of the poi made from it were obtained from the 13 factories on the island of Oahu, to learn whether the various brands of poi on the market were of the same general quality and fermented by similar organisms. The results of tests of these samples warranted the conclusion that, as a rule, all the factories were producing a very similar product, and justified the assumption that a detailed study of poi from any one of them would be representative of the commercial product found on the market. The detailed studies were therefore confined to the product of a single factory which supplies approximately one half of the poi produced on the island of Oahu. Only the results obtained with products from this source are considered in this bulletin.

Thirty-five samples of taro and poi were examined during a period of three years. In each case special attention was given to a study of the microorganisms on the taro prior to cooking, immediately following cooking but before peeling, after peeling, and in the poi at periodic intervals during the fermentation.

Plate Culture Method—Serial dilutions and solid culture media were used in the plate culture method of determining the numbers and types of microorganisms on the taro and in the fermenting poi. Nutrient agar plus 1 percent of glucose proved to be the most satisfactory of the various media employed. Poi extract media, prepared by adding 0.1, 0.25, 0.5, and 1 percent, respectively, of poi extract to 1.5 percent agar water base, with and without glucose added as a source of carbohydrate, were less satisfactory. The data obtained with the poi extract media were discarded, because the results were irregular, the organisms usually made scant growth, and, as a rule, the turbidity of the media prevented accurate counting of the very small colonies.

The taro corms used were of average size, each weighing about 500 grams prior to cooking. They were selected at random from the carload of taro as it went into the hooded inclosure. The taro was cooked and prepared under factory practice and later was taken to the laboratory for analysis. Only the outside portions of the taro corms were used in the plating analysis, since it had been shown earlier that the inside portions were sterile. In the case of the unpeeled corms (cooked and uncooked), the outside portion used was a layer about one half inch thick; and an additional layer, one fourth to one half inch thick, constituted the sample from the peeled corms. About one half of the outside surface of each corm was used in preparing the sample to be examined.

Five pound samples of the poi used in the investigation were obtained directly from the factory. The general practice was to take the samples immediately after the final step in the prepara-

tion of the poi namely, the crushing and mixing of the corms with water. Ordinarily these samples were incubated in the laboratory under conditions identical with those of the factory. In order to follow the course of fermentation in any one sample, it was necessary to continue the examination over a period of six days. This period was deemed sufficient since poi older than six days is seldom eaten. The age of the samples was timed from the crushing of the corms. Thus, the term "zero-hour" poi signifies that plating was done within 10 to 15 minutes after the corms had been crushed, but that the poi was not incubated; and, likewise, the terms six-hour poi, one-day poi, and so forth, signify that the poi had undergone the designated time of incubation prior to analysis.

Each plating sample of poi was made from five aliquot portions of the original factory sample. These were thoroughly mixed in each case to obtain a representative sample for analysis. A 10 gram sample of this representative mixture was then macerated in 90 cubic centimeters of sterile distilled water in preparation for the subsequent dilutions. Maceration was done by means of a flattened glass rod in a closed beaker, both rod and beaker having been previously sterilized in a dry oven at 160° C. for two hours. Since neither taro nor poi is readily miscible with water because of its starchy nature, considerable care was taken to obtain a homogeneous suspension. Following maceration, the water mixture of the sample was violently shaken 25 times. The resulting suspension usually had the consistency of skimmed milk. One cubic centimeter of this suspension was then transferred to water blanks and the dilutions were continued in series.

Five plates were poured from each dilution selected for counting. The colonies appearing visible with the aid of the Phelan plate counter were counted after five days of incubation at 35°C. Only those plates containing between 30 and 300 colonies each were used in determining the numbers of microorganisms. Counts of colonies were not reserved for consideration if the probable error was greater than 2 percent of the mean count.

Histological Methods — Histological studies were deemed necessary in the later phases of the study to show whether the bacteria responsible for the fermentation might be contained in the tissues of the taro corms. One half inch cubes of raw unpeeled taro, cooked unpeeled taro, and cooked peeled taro corms were prepared for histological study by the ordinary methods for paraffin sectioning. Only those fixatives were used which had proved most satisfactory in previous demonstrations of bacteria in plant tissues, namely, Wallin's modified Flemming's solution, Murray's fixative, and Zenker's fluid (*2*). The MacCallum modification of the Gram stain was used almost exclusively as a staining method. The sections were cut as thin as 5 micra.

Determination of pH—The hydrogen-ion concentrations of the variously treated corms and of the poi were determined with a hydrogen-ion potentiometer. This device gave more ac-

curate results than did the colorimetric method, since the solutions to be tested were usually turbid, and for this reason gave a very poor shade of color for comparison.

Isolating and Identifying Organisms—It was soon realized that the isolation and identification of all the organisms found in the plate cultures of taro and fermenting poi would be an endless task. Attempts were made, therefore, to study critically only the principal organisms found at the various stages of the fermentation and not only to isolate and identify those organisms responsible for the fermentation, but also to ascertain their sources and means of entry. The organisms developing on each plate were studied and note was taken of the various types of colonies. Colonies distinctly different in colony characteristics were isolated from the plate cultures into 1 percent glucose broth at the various stages of the fermentation.

The purity of each culture was assured before further steps were taken to study its characteristics. Data on the morphology of the cells and on the cultural, physical, and biochemical characteristics of each culture were tabulated according to the requirements of the descriptive chart of the Society of American Bacteriologists. It was not deemed necessary to obtain information on the pathogenicity of each culture. The cultures were typed to key characteristics (*8*). In addition to these methods of classification, type species of the more important organisms were later used as standards for comparison. Additional characteristics of the fermentative abilities of the more important microorganisms were obtained on xylose, arabinose, melezitose, starch, rhamnose, mannitol, and salacin. The data on the fermentation of these carbohydrates are not included, since the reactions of the organisms isolated and classified are already more or less well established. The works of Weinstein and Rettger (*43*), and of Hunt and Rettger (*23*) were especially helpful in classifying the *Lactobacillus* species.

Results

Examination of Taro—The results obtained from the study of 10 taro corms prepared for poi making entirely under factory conditions are shown in figure 2 and in table 4.

TABLE 4.—NUMBERS OF ORGANISMS ON TARO CORMS PREPARED FOR POI ACCORDING TO FACTORY PRACTICE.

(Counts expressed in thousands of colonies per gram)

Corm sample	On unpeeled corm before cooking	On unpeeled corm after cooking	On corm after peeling
No. 1	31,000	1,350	190
No. 2	48,000	4,850	775
No. 3	31,600	2,700	1,990
No. 4	29,600	9,520	2,240
No. 5	56,300	927	829
No. 6	52,100	3,400	1,621
No. 7	98,000	4,300	330
No. 8	34,500	7,582	1,040
No. 9	79,000	5,118	292
No. 10	41,700	2,020	1,114

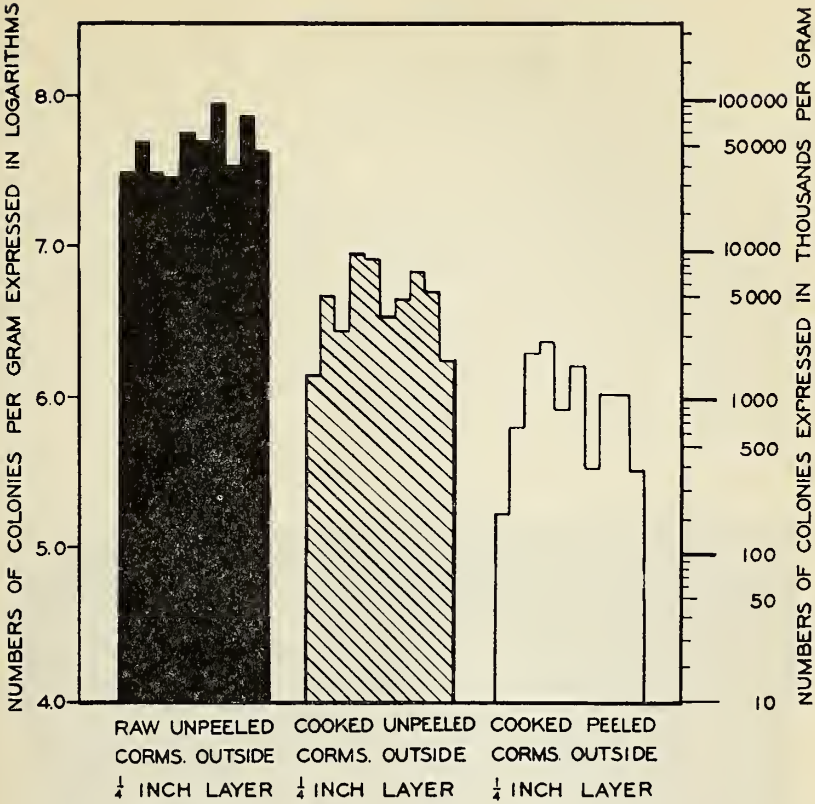

FIGURE 2.—Numbers of organisms per gram on corms prepared for poi according to factory practice.

As shown in table 4 there was very little agreement between the numbers of organisms on the various corms prior to heating. This lack of agreement and the fact that in no instance was the exterior surface of the corms completely sterile after they were cooked made it difficult to ascertain the efficiency of heat at various levels of the load of taro. Such lack of agreement was to be expected, since the degree of cleanliness of the corms prior to heating varied within rather wide limits. Such a chance selection of corms prior to heating included those with considerable soil adhering and those comparatively free from soil. As previously stated, the corms usually were not washed or cleaned prior to heating.

It will be noted that the cooked unpeeled corms showed a much smaller number of organisms than did the unpeeled corms before cooking. It is not believed, however, that such a reduction in numbers was due entirely to heating, since the water running over the taro after the cooking served to remove much of the adhering soil and tuber epidermis that had been softened by the steam. A further marked reduction was noted after the corms were peeled and trimmed before being crushed. Peeling

and trimming usually are begun as soon as the corms are cool; thus, contamination is possible for only the short time intervening. Usually the corms are trimmed with knives, although the epidermis may easily be removed by hand. The corms, following the removal of the outside portion, are washed several times under running water.

A very cosmopolitan flora was generally found in the plating analysis of the outside of the corms before heating, as indicated in figure 3 A. Most of the organisms on the outside layers were typical soil forms, including many aerobic spore-forming and nonspore-forming bacteria, chromogenic forms, typical soil spreading forms, a few common fungi, and actinomyces. None of them were found in the later stages of the poi making. The outside layer of the cooked unpeeled corms showed approximately the same types of organisms.

The organisms on the taro after factory peeling showed, as a rule, an approximately pure culture of small pin-point, lenticel-

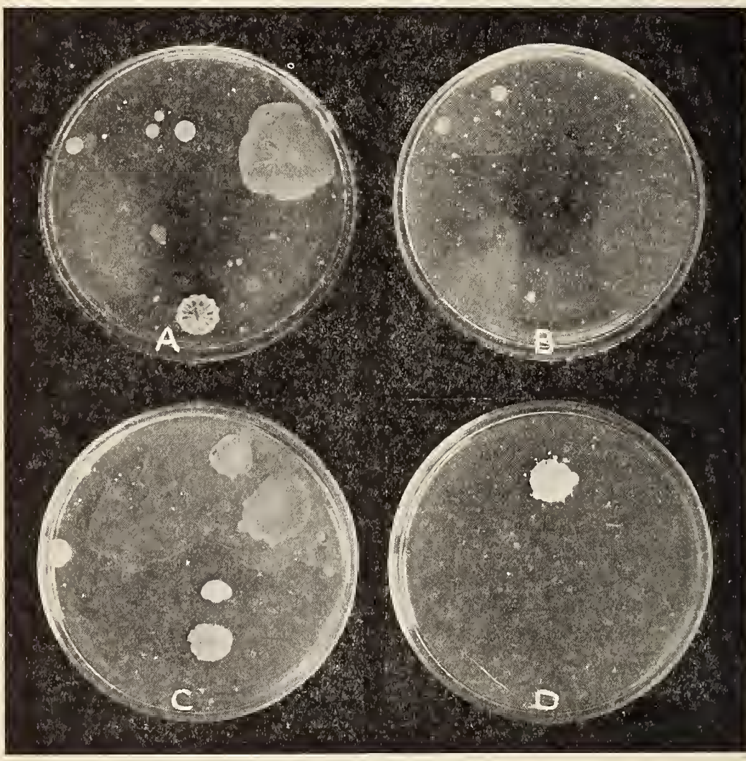

FIGURE 3.—Typical colonies on 1 percent of glucose agar plates after five days of incubation at 35° C.: A, Raw, young taro fresh from the soil; B, outside ¼-inch layer of taro corms steamed and peeled according to factory practice; C, zero-hour poi; D, six-hour poi. (Dilutions, A, B, and C, 500 thousand, and D, 1 million.)

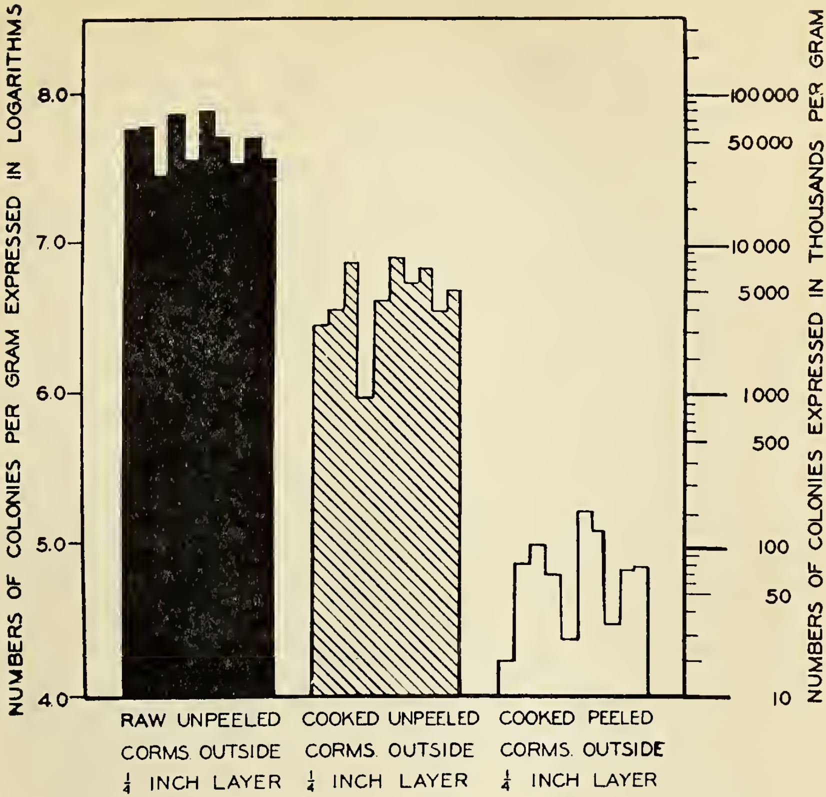

FIGURE 4.—Numbers of organisms per gram on taro corms heated and cooled according to factory practice, but peeled under laboratory conditions.

shaped, sub-surface white colonies, as shown in figure 3, B. More than 50 cultures were isolated from the plates poured from samples of the cooked peeled taro. Most of these were high acid producing forms. Five different species were isolated from plates at this stage of the fermentation, namely, *Lactobacillus pastorianus, L. delbrucki L. pentoaceticus, Streptococcus lactis,* and *S. kefir.* Which of these organisms was predominant was not determined.

Conditions prevailing in the process of poi making up to this stage suggested the possibility that the high acid-producing forms had been on the taro corms, or in the outside epidermal tissue, before heating. The prevalence of these organisms under the outside epidermal layer of the corms immediately after cooking also indicated the presence of the organisms in rather large numbers. Two procedures were therefore used to determine whether they were on the taro before heating. Ten corms were selected and prepared like those given in table 4 except that peeling was done in the laboratory under carefully controlled conditions, rather than in the factory. The number of

microorganisms found on these corms by the plate culture method are shown in figure 4 and in table 5.

TABLE 5.—NUMBERS OF ORGANISMS ON TARO CORMS HEATED AND COOLED IN THE FACTORY, BUT PEELED UNDER ASEPTIC CONDITIONS IN THE LABORATORY

(Counts expressed in thousands of colonies per gram.)

Corm sample	On unpeeled corms before cooking	On unpeeled corms after cooking	On corms after peeling in the laboratory
No. 1	56,300	2,800	16
No. 2	59,000	3,400	70
No. 3	28,000	7,700	109
No. 4	72,000	950	59
No. 5	37,100	5,000	22
No. 6	77,500	8,200	160
No. 7	48,500	5,900	139
No. 8	33,000	7,500	28
No. 9	51,000	3,800	72
No. 10	37,000	4,100	75

Table 5 shows the same irregularity in numbers of organisms in the various corms as had been previously observed. A general reduction from more than 1,000,000 to less than 100,000 organisms per gram of outside corm, or one tenth of the original, was obtained when the corms were peeled in the laboratory.

The same species of the high acid-producing organisms were isolated and found to be abundant on the corms peeled under controlled conditions in the laboratory as under factory conditions, indicating that the organisms were originally on the corms and were not contaminants added in the peeling and washing processes in the factory.

Attempts to demonstrate, by histological methods, the presence of these organisms in the tissue cells were unsuccessful. Unsuccessful attempts were also made to show the presence of the organisms on the raw uncooked taro, since the types of organisms found made conditions unfavorable for their demonstration.

Examinations of poi—The number of organisms found in poi samples Nos. 2, 5, 10, 12, and 15 are shown in table 6.

TABLE 6.—DAILY VARIATION IN MICROBIAL COUNT OF POI SAMPLES DETERMINED ON ONE PERCENT GLUCOSE AGAR AFTER FIVE DAYS OF INCUBATION AT 35° C.

(Counts expressed in millions of colonies per gram.)

Age of poi at time of examination	Sample No. 2	Sample No. 5	Sample No. 10	Sample No. 12	Sample No. 15
0 hour	70.50	147.00	212.00	308.00	146.00
6 hours	104.00	227.00	308.00	330.00	173.00
12 hours	103.00	239.00	250.00	236.00	147.00
18 hours	104.00	269.00	228.00	210.00	107.00
1 day	104.00	316.00	184.00	168.00	94.00
2 days	85.10	103.00	33.80	58.80	28.80
3 days	20.40	47.80	21.20	31.40	9.48
4 days	5.08	10.20	23.80	18.10	5.75
5 days	6.67	7.93	12.70	6.15	4.89
6 days	7.61	10.07	12.00	6.08	9.15

Daily variations in count of organisms in samples of poi are shown graphically in figure 5. The pH values obtained for the raw and cooked corms and for the above-mentioned samples of poi over a six-day period are shown in figure 6. The data are illustrative of the general results obtained in the examination of the 35 samples studied.

Similarities in the general nature of the counts of microorganisms in the different samples of poi are to be noted. In each sample the number of microorganisms increased rapidly during the first 24 hours, after which there was a decline to the minimum on about the fifth day. The increase in the first 24 hours is believed to have been due not only to the addition of water, which made the mass less concentrated, but also to the increased availability of the various sugars released from the tissue cells during the crushing process. Although the larger proportion of the samples showed a peak in the population curve within the first 24 hours, some of the samples varied in this respect. Samples Nos. 10, 12, and 15 reached a peak in the first six hours of incubation, whereas sample No. 5 constantly rose in number of organisms for 24 hours. Sample No. 2 maintained its maximum population for about 18 hours. These differences in peaks may be explained by differences in number of organisms on the various corms used to prepare the poi, since the number of organisms in the initial fermentation also varied considerably. The data in tables 4 and 5 show a rather wide variation in number of organisms on the corm at the various stages of preparation. An initial count of 70.8 millions of organisms per gram of poi was found for sample No. 2, whereas counts of 147, 212, 308, and 146 millions of organisms were recorded for samples Nos. 5, 10, 12, and 15, respectively.

The hydrogen-ion concentration of uncooked taro corms approximated pH 6.6. After the corms were heated the average pH value was found to be about 6.37. The acidity of the samples of poi examined rose the most rapidly within the first 24 hours, at the end of which time the pH value closely approximated 4.9. After the first 24 hours there was a general rise in acidity until pH values between 3.8 and 4 were reached. Samples of poi incubated longer than 10 days did not, as a rule, show a pH value lower than these, except in one case in which, after eight days of incubation, the pH value was 2.7. In general, the flora of poi more than five days old tended, as a rule, to make conditions more alkaline rather than more acid.

The study of types of microorganisms in poi during fermentation shows three phases: first, a phase in which a very cosmopolitan flora exists after the crushing of the corms, the addition of water, etc.; second a phase lasting bewteen six hours and three or four days in which the microflora is chiefly that of the high acid-producing forms; and third, a phase in which mycoderms, yeasts, and oidial species become increasingly prevalent.

The fermentation of poi bears a close analogy to the souring

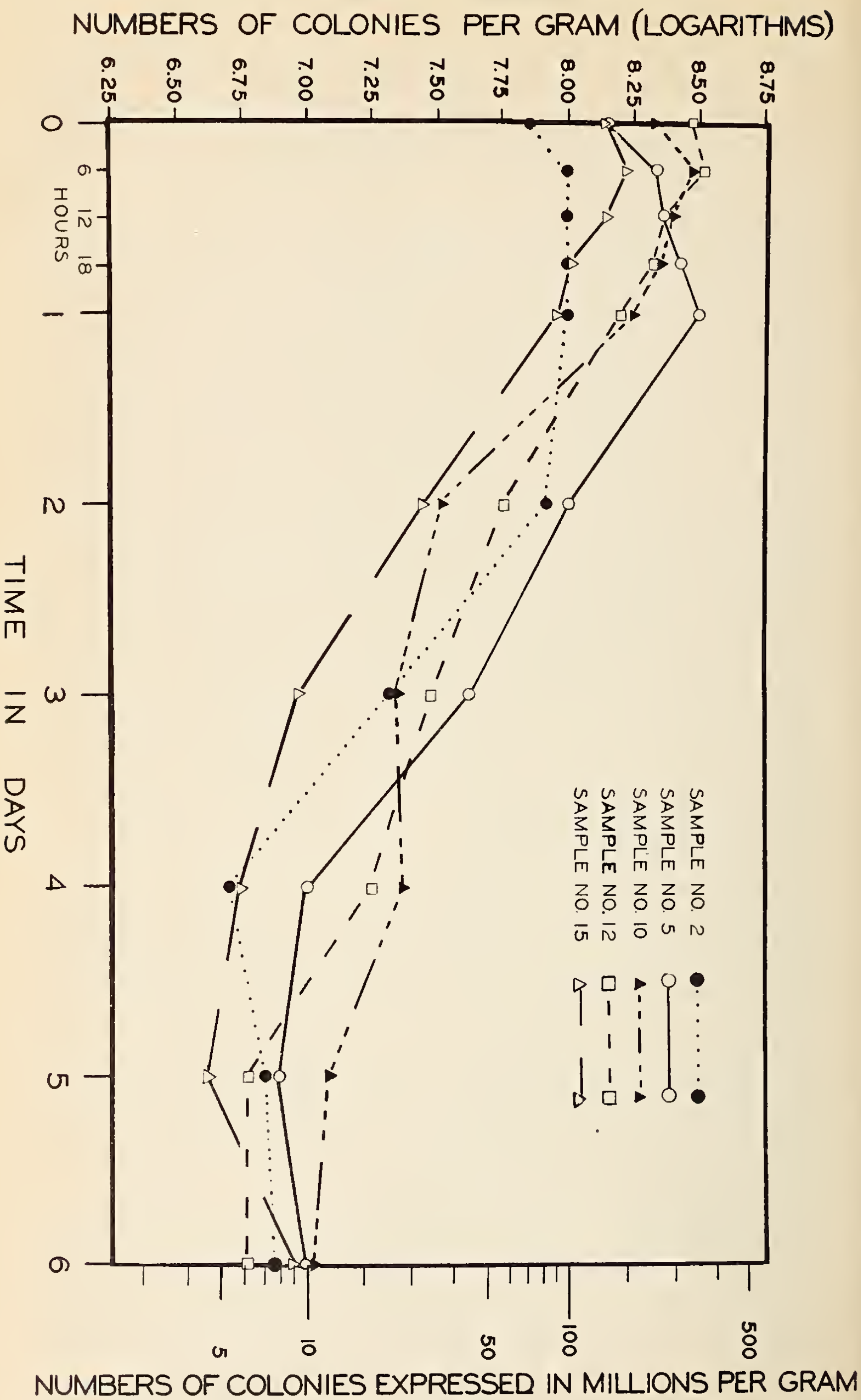

FIGURE 5.—Daily variation in microbial count of poi samples determined on 1 percent glucose agar after 5 days of incubation at 35° C.

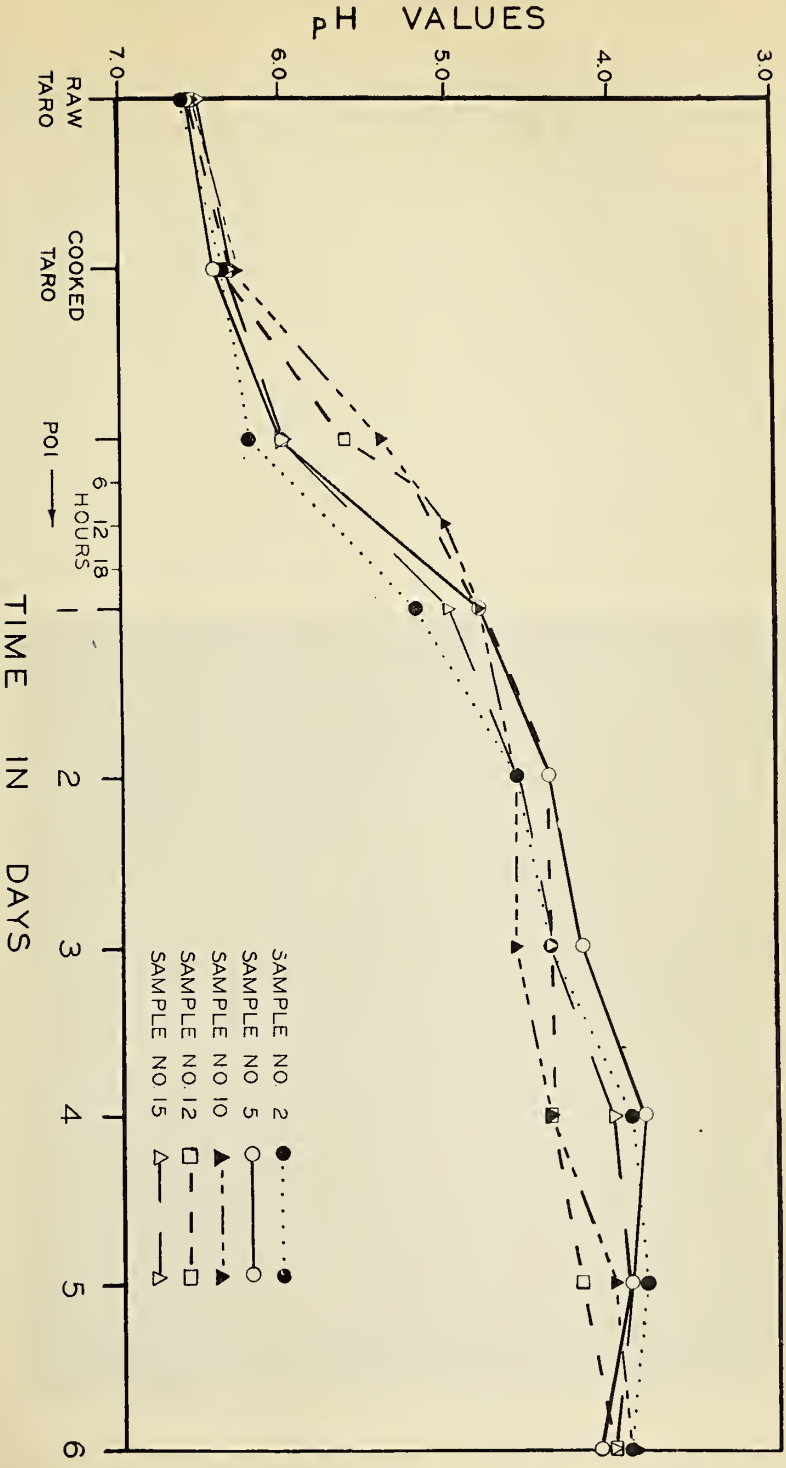

FIGURE 6.—Hydrogen-ion values at various intervals of raw taro corm and steamed corm samples and resulting poi.

of milk in the types of the organisms concerned and in the nature of the fermentation. The acid fermentation is a result of the metabolic action of *Lactobacillus* species and of *Streptococcus* species on the readily fermentable carbohydrates. The five species identified as *L. pastorianus*, *L. delbrucki*, *L. pentoaceticus*, *S. lactis* and *S. kefir* were found in all stages of the fermenting poi. Poi that has become very acid after three or four days of fermentation makes an especially favorable medium for the growth of mycoderms, oidia, and acid-resisting yeasts. The latter stages of the fermentation are therefore characterized by a prevalence of these forms.

The organisms found in freshly made or zero-hour poi represented many genera, including *Escherichia coli*, *Aerobacter aerogenes*, *Pseudomonas fluorescens*, chromogenic bacteria, spore-forming rods, and various other forms in rather large numbers. An examination of the water used in the mixture, and of the washings from the hands of the attendants, and from the containers, utensils, and knives used showed that these were the principal sources of contamination by the above-mentioned bac-

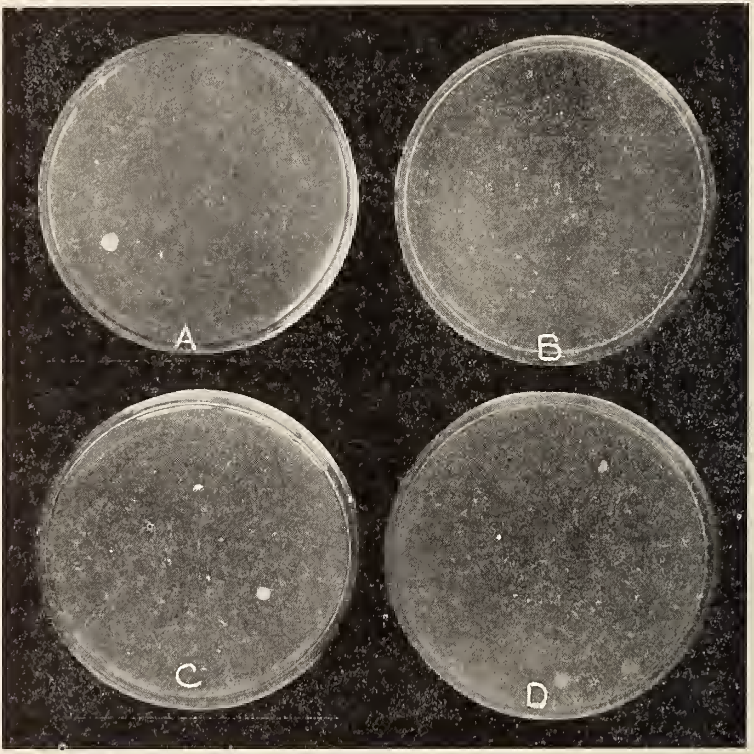

FIGURE 7.—Typical colonies on 1 percent glucose agar plates after 5 days of incubation at 35° C.: A, 12-hour poi; B, 18-hour poi; C, 24-hour poi; D, 48-hour poi. (Dilutions, A, B, and C, 1 million, and D, 100 thousand.)

terial forms. They persisted for only three or four hours, however, due to the unfavorable growth conditions created by the acid-producing organisms. The presence of some of these common organisms in fresh poi is shown in figure 3 C, and their absence from the same sample after six hours in figure 3 D.

Poi that had been incubated from six hours to three days showed an almost pure flora of the small pin-point colonies characteristic of the acid-producing species. Occasionally a few colonies of yeasts and of mycoderms appeared during this interval, but at no time did they become prevalent (fig. 7). During the phase of the fermentation occurring between the sixth hour and the third day the poi became increasingly acid and that made from some varieties of taro changed in color from purple to pink, due to the reaction of a natural plant indicator present.

Each sample of poi examined during the three to six-day interval of fermentation showed an increasingly predominance of mycoderms, yeasts, and oidia, as shown in figure 8. *Mycoderma cerevisiae* and *Oidium lactis* were exceedingly prevalent during this period. Only two typical yeasts were isolated during

FIGURE 8.—Typical colonies on 1 percent glucose agar plates after five days of incubation at 35° C.: A, 72-hour poi; B, 96-hour poi; C, 124-hour poi; D, 144-hour poi. (Dilution, 100 thousand.)

the fermentation of the poi, and they were not thoroughly identified. They were not found to be especially abundant during any stage of the fermentation, but their presence was indicated by the production of carbon dioxide and minute quantities of alcohol.

Microscopic examinations of direct smears from samples of taro and of poi, each in the dilutions used in plating, were made to ascertain the morphological groups of organims present. The technique of Breed and Brew (*11*) proved to be more satisfactory than that of Cholodny (*15*). Attempts to estimate quantitatively the number of organisms on the slides by the Breed method were not made since counting was made difficult by irregularity in thickness of the taro and poi films. Cells typical of streptococci, lactobacilli, long budding strands of mycodermal filaments, typical oidial cells, and occasionally yeasts in stages of budding were found in all samples of the poi at all stages of fermentation. The respective abundance of these various types corresponded rather closely with the results obtained in the plate culture study.

The data on the relative abundance of the two major groups of organisms found in the poi by the plate culture method are shown graphically in figure 9.

A total count was made of all organisms appearing on the glucose agar plates and attempts were made to grossly differentiate between the morphological characters of the two groups. Small lenticel-shaped, white colonies (fig. 7, B) were considered to be representative of the high acid-producing group. Gross appearing colonies typical of mycoderms, oidia, and yeasts were considered as representative of the latter type of flora. Isolations of such colonies and their identification substantiated these assumptions. The results are tabulated in table 7.

TABLE 7.—TOTAL NUMBERS OF COLONIES AND VARIATIONS IN RATIO BETWEEN NUMBERS OF PIN-POINT ACID-FORMING COLONIES AND THE MYCODERMS, YEASTS, AND OIDIAL COLONIES IN A SAMPLE OF POI DURING A SIX-DAY INCUBATION AT 35° C.

Age of poi at time of examination	Total number of colonies	Pin-point acid-forming bacteria		Mycoderma, yeasts, oidia	
	Millions per gram	*Millions per gram*	*Percent*	*Millions per gram*	*Percent*
0 hour	324.40	268.20	82.70	1.00	0.30
1 day	170.80	161.50	95.00	1.20	0.70
2 days	54.00	50.70	94.84	2.25	4.16
3 days	23.75	21.37	90.80	1.50	6.20
4 days	16.80	13.27	78.99	3.53	21.01
5 days	8.77	6.10	70.10	2.67	29.90
6 days	7.27	2.75	38.10	4.52	61.90

The data in table 7 illustrate very clearly the general shift in the types of organisms in the fermenting poi. Acid-forming bacteria represented between 80 and 95 percent of the total flora

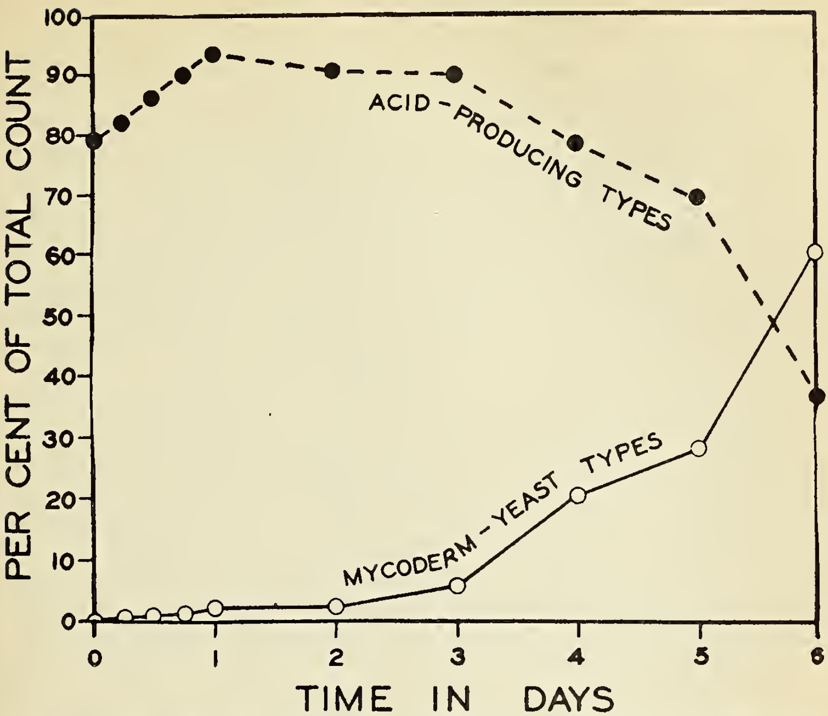

FIGURE 9.—Varying percentages of acid-producing and mycoderm-yeast colonies on poi samples during a six-day fermentation period.

during the first three days, whereas the mycoderm group represented between 0.3 and 6 percent of the total flora. The pin-point colonies decreased from 78.99 percent of the total flora on the fourth day to 70.1 percent on the fifth day and 38.1 percent on the sixth day, whereas the mycoderm flora increased from 21.01 to 29.9 to 61.9 percent on the same days. Poi averaging five days of incubation usually showed a flora consisting of 50 percent of small pin-point colonies and 50 percent of the mycodermal type.

Pure cultures of *Lactobacillus delbrucki, L. pastorianus, L. pentoaceticus, Streptococcus lactis, S. kefir, Mycoderma cerevisiae, Oidium lactis* and the two species of yeasts were used individually and in various combinations as starters in the making of poi under controlled conditions in the laboratory. Data resulting from these studies confirmed the fact that a composite inoculum of these organisms was necessary to give the odor, color, taste, texture and consistency characteristic of the commercial product.

Discussion of Rsults

The lack of experimental data in the literature on fermentation of poi precludes a comparison of the results obtained by various investigators. Although Miller (*34*) reviews briefly the microbial fermentation of poi, she does not give experimental

data on the type of the fermentation, the chemical changes resulting therefrom, or the kinds of microorganisms involved.

The results of this study support the conclusion that the fermentation of poi is due to the activities of certain acid-producing bacteria that gain entrance to the poi from the taro corms through insufficient heating and cooking of the corms and through chance sources of contamination in the factory. The evidence obtained shows that, although many bacteria commonly occurring in soil, water, and air may be present in the early stages of poi making, they are relatively unimportant in the true fermentation. A decrease in the number of these organisms and their failure to act in the fermentation process are due chiefly to their inability to withstand semi-anaerobic conditions and increase in acidity of the fermenting product.

The fermentation of poi results from chance inoculation of the crushed corms with the high acid-producing organisms. The study of poi making over a three year period failed to reveal any case introducing starters or inoculants to facilitate fermentation. The memoirs, writings, and notes of the early missionaries and travelers in the Hawaiian (Sandwich) Islands afford evidence that the fermentation of poi by the native Hawaiians resulted from pure chance. The lack of scientific training and of a general understanding of the process by those in charge of the industry is partly responsible for such a condition now existing.

Although chemical evidence is lacking at the present time, there is little doubt that the fermentation of poi is a complex process. The chemical analyses reported by Chatfield and Adams (*13*) serve to show that taro affords a suitable medium for the growth of the more common saprophytic microorganisms. The immediate evidences of the fermentation, such as the evolution of carbon dioxide and increase in acidity, indicate that the carbohydrates are among the first substances to be attacked.

There is reason to believe that during the period of acid production considerable starch is hydrolyzed and thus converted into available energy. However, Miller's data (*34*) fail to show that such hydrolysis occurred. Her analyses show 10.52 percent of starch in fresh poi (pH ?), 10.01 percent in sour poi (pH 3.5), and 9.935 percent in sour poi (pH 3) as determined by acid hydrolysis. Similar values of 9.7, 9.66, and 9.6 percent starch, respectively, were accounted for by saliva hydrolysis in the samples of poi used. Since a pH value is not given for the fresh poi, the sample very probably was comparatively acid at the time of analysis, and hydrolysis had already occurred. This assumption is further warranted by the fact that only infinitesimal differences in the percentage of reducing sugars in the three samples of poi were noted. The sucrose values varied from 0.901 percent in the fresh poi (pH ?) to 0.0725 percent in the sour poi (pH 3.5) to 0.159 percent in the sour poi (pH 3).

In most of the samples examined the chief changes in the poi obviously resulted from the fermentations produced by *Streptococcus* species and by *Lactobacillus* species. The activities

of these microorganisms in the fermentation of milk, sauerkraut, ensilage, and various sugar mixtures are well known. Their importance in the fermentation of poi rests on their ability not only to live under conditions that are more or less unfavorable for other microorganisms, but to bring about chemical changes resulting in the production of various by-products. The acid-producing microorganisms described are able to produce not only large quantities of lactic acid, but also moderate quantities of acetic, propionic, succinic, and formic acids, in addition to traces of acetone and alcohol. The fermentation of poi is obviously one of production of many organic acids with lactic acid predominating. It is probable that acetic acid also appears in appreciable quantities during the fermentation.

Species of yeasts, mycoderms, and oidia were not found to be the principal agents of the fermentation. Although microscopic-plate tests showed that these organisms were present in all stages of the fermenting poi, they were not found in sufficient numbers to account for the major chemical changes. It is highly possible that the larger part of the carbon dioxide, as well as the pleasant fruity odors and flavors in the old poi were caused by esters produced by the yeasts. The saccharomycetous microorganisms multiplied in the fermenting poi because of the optimum conditions brought about through the activities of the lactic groups and provided the characteristic bouquet principle.

Improving The Poi Industry

A consideration of conditions prevailing in the poi industry makes possible several suggestions for its general improvement. Increased unity and organization among the various factories are needed. In addition, the industry might be improved by the employment of persons having a better understanding of methods of modern production and with a basis of scientific training.

Although the quality of poi from 13 factories was found to be remarkably uniform, a still more consistent product could be produced with the aid of starters or inoculants. Several cases of the failure of the poi to undergo the typical fermentation, resulting in an inedible product because of its butyric nature, were observed. This happens at untimely intervals at a tremendous loss to the various factories. It is reasonable to believe that typical fermentation would be assured by the use of a starter.

In like manner the mode of incubation should be improved. Laboratory tests showed that a more uniform product could be produced if a temperature of 37° C. were maintained during the fermentation, since this temperature is optimum for the organisms responsible for the fermentation. The use of a small cabinet or room adjusted to a temperature of approximately 37° C. would involve little expense or expansion in the average factory, but would aid considerably in producing a more uniform quality of the product.

Machine grinding is used in most of the factories, but hand

crushing and hand grinding of the taro are not uncommon. The latter method of preparation seems to have many unsanitary aspects.

General factory conditions could be improved. The poi is usually produced and sold in one-room buildings, the surroundings of which are not especially inviting to the purchasing public. Steaming, peeling, washing, crushing and the other preparations of taro usually take place in a very small area. A division of the average factory into several rooms for development of the various stages of the poi making process would serve not only to increase the efficiency of the workmen, but also to improve the general appearance of the plant. The adoption of a more sanitary mode of dress by the workmen would also have a good effect on the industry (fig. 1).

SUMMARY AND CONCLUSIONS

The following conclusions are drawn from the results of the experimental work.

Poi is a carbohydrate (starchy) food prepared by allowing the crushed steamed corms of the taro plant to undergo an acid fermentation, due primarily to bacteria, and secondly to species of yeasts, mycoderms and oidia. The general indication of the fermentation are immediate changes in color, taste, texture and odor of the poi.

The fermentation resulting in poi is very similar to that occurring in the souring of milk. The bacteria commonly found during the various phases of the fermentation and shown to be the causal agents of the acid production included *Lactobacillus delbrucki, L. pastorianus, L. pentoaceticus, Streptococcus lactis* and *S. kefir. Mycoderma cerevisiae* and *Oidium lactis* and several species of yeasts were exceedingly prevalent in the latter stages of the fermentation.

The fermentation of poi may be divided into two phases with respect to the organisms concerned. In the first phase bacteria of a high acid-producing type were found to predominate, with a consequent rapid increase in the production of acid. Acid productino was usually very rapid within the first 24 hours, during which time the acidity commonly increased from a pH 6.3 (freshly ground taro corms) to pH 4.5. Thereafter, the acidity increased more gradually until it reached an average of pH 3.8. The lowest pH was usually obtained during the fifth or sixth day of the fermentation. In the second phase of the fermentation, from the third to the sixth day, a flora of yeasts, mycoderms, and oidia were increasingly prevalent in the poi. These organisms evidently found the acid product to be a very favorable medium for growth although no appreciable changes were brought about in the poi through their activities.

The organisms responsible for the fermentation were abundant on the steamed taro corms immediately following heating. It was shown that these organisms gain entrance to the crushed

taro or poi as a result of insufficient heating and cleansing of the corms. Grinding of the crushed corms aids in breaking the bacterial clumps or colonies on the corms, and therefore makes possible not only increase in numbers of organisms, but also their distribution rather homogeneously throughout the fresh poi. The rapid fermentation usually resulting is evident immediately in increased bacterial numbers and in acidity.

A study of the numbers of organisms on the taro showed that although the processes of preparing the taro for grinding tended to remove or to decrease those originally on the corms, the corms at the time of crushing retained about 15 percent of their original number of organisms. Multiplication and activity of the least desirable organisms were quickly inhibited by activity of the acid-producing bacteria.

The number of organisms in poi usually reached a peak population during the first 24 hours, after which they rapidly and steadily declined until about the fifth day, when they were at the minimum.

Data were obtained showing that, whereas the acid-producing bacteria decreased in number during the six days of incubation, the number of mycoderms, yeasts and oidial species steadily increased. Poi that had undergone five days of incubation at room temperature, 25° C., showed a microflora of which 50 percent of the total number of colonies by the plate culture method were of the acid-producing type and about 50 percent of the colonies were of the oidial type.

The chemical aspect of the fermentation is not developed in this study because investigations in that phase of the subject are now being conducted by Dr. L. N. Bilger and Mr. H. Y. Young of the University of Hawaii.

LITERATURE CITED

1. ALLEN, E. K. AND ALLEN, O. N.
1932. *A Study of the Bacterial Fermentation of Poi.* Jour. Bact. 23; 63-65.

2. ALLEN, E. K. AND ALLEN, O. N.
1933. *Atttempts to Demonstrate Symbiotic Nitrogen-Fixing Bacteria within the tissues of* CASSIA TORA L. Amer. Jour. Bot. 20: 79-85.

3. BAILEY, L. H.
1928. *The Standard Cyclopedia of Horticulture* (v. 3) 3311-3313. New Edition. The MacMillan Co., New York. 3639 pages.

4. BAIROS, M. B.
1932. Personal Communication. September 26th.

5. BARRETT, O. W. and COOK, O. F.
1910. *Promising Root Crops for the South. I. Yautias, Taros and Dasheens. II. Agricultural History and Utility of the Cultivated Aroids.* U. S. D. A. Bureau Plant Ind. Bul. 164. 43 pages.

6. BARRETT, O. W.
1928. *The Tropical Crops,* pp. 375-377. The MacMillan Co., New York.

7. BATES, G. W.
1854. *Sandwich Islands Notes by a Haole,* pp. 122-123. Harper and Brothers, New York.

8. BERGEY, D. H.
1930. *Manual of Determinative Bacteriology.* Williams and Wilkins Pub. Co., Baltimore, Md. 589 pages.

9. BLACK, O. F.
1918. *Calcium Oxalate in the Dasheen.* Amer. Jour. Bot. 5: 447-451.

10. BORG, J.
1927. *Descriptive Flora of the Maltese Islands.* pp. 800-801. Malta Government Printing Office.

11. BREED, R. S. AND BREW, J. D.
1918. *Counting Bacteria by Means of the Microscope.* New York Agric. Sta. Circ. 58.

12. BROWN, F. B. H.
1931. *Flora of Southeastern Polynesia. I. Monocotyledons.* Bernice P. Bishop Museum Bul. 84: 132-135.

13. CHATFIELD, C. AND ADAMS, G.
1931. *Proximate Composition of Fresh Vegetables.* U. S. D. A. Circ. 146. 24 pages.

14. CHEEVER, H. T.
1850. *The Island World of the Pacific.* Chapter 5: 99-101. Harper and Brothers, New York.

15. CHOLODNY, N.
1930. *Ueber Eine Neue Methode zur Untersuchung der Bodenmikroflora,* Arch. f. Mikrobiol 1: 650-652.

16. COOK, CAPTAIN JAMES
1784. *A Voyage to the Pacific Ocean* 2: 235-236. W. and A. Strahan, London, England.

17. COOK, O. F. AND COLLINS, G. N.
1903. *Economic Plants of Porto Rico.* Contribution from the U. S. Nat. Herb. 8: part 2, 122-123.

18. CRAWFORD, D. L.
1930. *Some Observations on the Agricultural Situation in Hawaii.* University of Hawaii Occasional Paper 8.

19. ELLIS, WM.
1832. *Polynesian Researches* 1: 43-44. Fisher, Son and Jackson, London, England.

20. FREEMAN, O. W.
1927. *The Economic Geography of Hawaii.* University of Hawaii Research Publication 2: 55-56.

21. HIGGINS, J. E.
1907. *Taro.* L. H. Bailey: Cyclopedia of Agriculture 2: 629-631. MacMillan Co., New York.

22. HUBBARD, F. T. AND REHDER, A.
1932. *Nomenclatorial Notes on Plants Growing in the Botanical Garden of the Atkins Institution of the Arnold Arboretum at Soledad, Cienfuegos, Cuba.* Harvard Botanical Museum Leaflet 1:5.

23. HUNT, G. A. AND RETTGER, L. F.
1930. *A Comparative Study of Members of the Lactobacillus Genus, with Special Emphasis on Lactobacilli of Soil and Grain.* Jour. Bact. 20: 61-83.

24. JARVES, J. J.
1843. *History of the Hawaiian or Sandwich Islands.* page 68. Edward Moxon, London, England.

25. LANGWORTHY, C. P. AND DEUEL, H. J., JR.
1922. *Digestibility of Raw Rice, Arrowroot, Canna, Cassava, Taro, Tree-Fern and Potato Starches.* Jour. Biol. Chem. 52: 251-261.

26. LANGWORTHY, C. P. AND HOLMES, A. D.
1917. *The Digestibility of the Dasheen.* U. S. D. A. Bul. 612. 11 pages.

27. LIU, C.
1932. *Poi Making is Done Today by Modern Means.* Honolulu Star-Bulletin, Section 3, page 1, September 3rd.

28. LUM, K. C.
1933. *Less Poi is Being Eaten in Territory.* Honolulu Star-Bulletin, Section 3, page 1, July 15th.

29. LUND, A. S. T. AND KRAUSS, F. G.
1933. Personal Communication. January 31st.

30. MacCAUGHEY, V. AND EMERSON, J. S.
1913. *The Kalo in Hawaii.* Hawaii Forester and Agriculturist 10: (a) 186-193, (b) 225-231, (c) 280-288, (d) 315-323, (e) 349-358, and (f) 371-375.

31. MacCAUGHEY, V. AND EMERSON, J. S.
1914. *The Kalo in Hawaii.* Hawaii Forester and Agriculturist 11: (a) 17-23, (b) 44-51, (c) 111-123 and (d) 201-216.

32. MacCAUGHEY, V.
1917. *The Hawaiian Taro as Food.* Hawaii Forester and Agriculturist 14: 265-268.

33. MacCAUGHEY, V.
1917. *The Food Plants of the Ancient Hawaiians.* Scientific Monthly 4: 75-80.

34. MILLER, C. D.
1927. *Food Values of Poi, Taro and Limu.* Bernice P. Bishop Museum Bul. 37. 25 pages.

35. OCHSE, J. J.
1931. *Vegetables of the Dutch East Indies.* English edition. Buitenzorg, Java.

36. SAFFORD, W. E.
1905. *The Useful Plants of the Island of Guam.* Contributions of the U. S. Nat. Herb. 9: 69-71. Washington Government Printing Office, Washington, D. C.

37. SEDGWICK, T. F.
1902. *The Root Rot of Taro.* Hawaii Agric. Exp. Sta. Bul. 2. 22 pages.

38. STEENBOCK, H. AND GROSS, E. G.
1919. *Fat-Soluble Vitamins. II. The Fat-Soluble Vitamin Contents of Roots Together with Some Observations on their Water-Soluble Vitamin Content.* Jour. Biol. Chem. 40: 501-532.

39. STEWART, C. S.
1828. *Journal of a Residence in the Sandwich Islands.* pages 142-145. H. Fisher, Son and Jackson, London, England.

40. THRUM, T. G.
1879. *Varieties of Taro* (ARUM ESCULENTUM). Haw. Almanac and Annual for 1880. pages 28-29.

41. THRUM, T. G.
1886. *Taro*—COLOCASIA ANTIQUORUM. Haw. Almanac and Annual for 1887. pages 63-65.

42. THRUM, T. G.
1892. *Lapsed and Possible Industries in Hawaii-Nei.* Haw. Almanac and Annual for 1893. page 109.

43. WEINSTEIN, L. AND RETTGER, L. F.
1932. *Biological and Chemical Studies of the Lactobacillus Genus with Special Reference to Xylose Fermentation by* L. PENTOACETICUS. Jour. Bact. 24: 1-28.

44. WILSIE, C. P.
1933. Personal Communication, February 8th.

45. YOUNG, R. A.
1913. *The Dasheen, a Root Crop for the Southern States.* U. S. D. A. Bur. Plant Ind. Circ. 127: 25-36.

46. YOUNG, R. A.
1917. *The Dasheen: Its Uses and Culture.* Yearbook of the U. S. D. A. for 1916. pages 199-208.

47. YOUNG, R. A.
1924. *The Dasheen: A Southern Root Crop for Home Use and Market.* U. S. D. A. Farmer's Bulletin 1396. 35 pages.

48. YOUNG, R. A.
1924. *Taros and Yautias: Promising New Food Plants for the South.* U. S. D. A. Bul. 1247. 23 pages.